International Journal of Environment, Ecology,
Family and Urban Studies (IJEEFUS)
ISSN (P): 2250-0065; ISSN (E): 2321-0109
Vol. 8, Issue 3, Jun 2018, 35- 50

APPRAISAL OF EMBODIED ENERGY FOR RESIDENTIAL TYPOLOGIES FOR ENERGY CONSERVATION IN ANDHRA PRADESH, INDIA

SRIKONDA RAMESH, YOGESH J. PAREKH & MOHAN VAMSI S

Department of Architecture, School of Planning and Architecture, Vijayawada, Andhra Pradesh, India

ABSTRACT

Choices of material specification and construction methods can significantly change the amount of energy embodied in a building, as embodied energy content varies enormously among products and materials. Assessing the embodied energy of a material, component or whole building is often a critical and complex in nature as it dependent on architectural detailing, space-use specific specifications and available local materials and local technical know-how. The researchers are mostly focused on reducing the operational energy of the buildings because clients and users demand direct and visible energy savings. This paper deals Material efficiency in embodied energy considerations is emphasized as an important aspect of sustainable building, as indicated by the inclusion of the new basic requirement for sustainable use of resources with locally workable options to save embodied energy and energy cost for residential building as this land-use in general covers 45 to 50% of the land use in cities and Master Plans. According to the researchers, most of the buildings embodied energy relates to the structural system specifications (24%) and envelope design considerations (26%)... The option III of case III shows the maximum reduction of 52.29% in embodied energy (1.87XGJ/m2) as compared to all. The cost estimate of building materials also shows the reduction in the tune of 27.83% with respect (Rs.8934.65 per m2) to option I of Case II. The option II of the case I show the reduction of 32.91% in embodied energy (2.63XGJ/m2) and 25.73% in cost estimate (Rs.9,194.63 per m2) with respect to option I of Case II. The option III of case III indicates that the proper integrated use of alternative and low-cost technologies such filler slabs fly ash bricks in the foundation, hollow blocks of masonry and Mud chaska terracing not only reduces the embodied energy content but also reduces the unit cost of plinth area. The global warming and greenhouse gas emissions are among the biggest global problems on which material efficiency has a direct influence, so it is essential to land crucial to identify the appropriate material for the relevant component of the building to save the energy.

***KEYWORDS:** Energy Estimates; Quantity Survey; Conventional Design; Specifications And Development Controls*

Received: Apr 10, 2018; **Accepted:** May 26, 2018; **Published:** Jun 13, 2018; **Paper Id**.: IJEEFUSJUN20184

Original Article

INTRODUCTION

This paper deals with the Embodied Energy and Cost Analysis of the overall energy profile of a building using particularly the conventional and advanced building materials in India, which consumes an enormous quantity of energy. It is one of the major attention areas of the building industry at design process stage while working out the building specifications with specific reference to energy conservation options (Ramesh 2016). Most important of these stages from the point of view of energy intensity are Raw material acquisition and transportation and preparation, Manufacturing, Use and operation, Disposal and reuse. Several organizations such as CBRI, IITs, BMPTC, TERI and Architects / Engineers are working to evolve less energy intensive building material, but the end product of how such building materials can be effectively specified in the building design process is not being worked upon.

The major components of a conventional building, which are to be explored essentially with reference to the embodied energy consumption for the buildings, are mortar mixes, wall specification, roofing, terracing, flooring, plastering, plumbing, joinery, furnishings, and Interiors specifications. On the basis of the energy consumed for manufacturing the materials, common guidelines have been given by the concerned Industries. The socio-economic value of mineral extraction can be significant in some regions, and changes in the extraction industry can have important social consequences (Finnveden 2005). Söderholm and Tilton (2012) argue that economic depletion will occur long before physical depletion. Research by CSIRO has found that the average house contains about 1,000GJ of energy embodied in the materials used in its construction.

The energy consumption prepared through the two sources, i.e. questionnaire and literature was compared by Mohan Rai (1984) and it is found that there was only a slight variation of the mean energy cost of some important materials as given in the table 6.1. Verma *et al* (1984) emphasized the need of conserving the energy at the source level that is at the process level in manufacturing units by using high temperature insulations to save energy. Similarly Prakash (1992) suggested agricultural products and forest residues in drying of building bricks. Hajela *et al* (1992) elaborated the usage of inferior fuels in brick production. The production of advanced and novel-building materials with respect to the embodied energy consumption profile was emphasized by Mullick (1992) using the industrial wastes with reference to the source and its availability per annum for effective utilization in building industry. The role of Portland pozzolana cement in energy savings by improving the properties of the concrete and mortar was emphasized i.e addition of Pozzolana in optimum proportions with ordinary Portland cement improves several qualities of concrete like (1) Workability, (2) Heat of hydration, (3) Permeability, (4) Alkali-aggregate reaction etc. Common examples of pozzolanic materials are – (a) Natural pozzolanas like volcanic ash, diatomaceous earth and artificial pozzolanas, (b) Calcinated clays / shales etc. and (c) Industrial wastes like fly ash, fuel ash etc.

(Kumar *et al* 1998) further emphasized energy conservation and savings by using fly-ash sand-lime bricks, hollow blocks and Lime gypsum bricks. The compressive strength of hollow blocks was measured for different proportions of the fly-ash and cement. Similarly, the life cycle costing of PVC building materials and embodied energy have been reported by Mathur (2001). Embodied energy of the buildings can vary over a wide range depending upon the choices of building materials and construction techniques. RC frames, RC slabs, Hollow masonry, Burnt clay brick masonry, Madras terrace roofing and jack arch roofing represent common conventional options forming main structure of the buildings in India. Alternative building technologies such as stabilized mud blocks, pre-fabricated roofing system, masonry vaults, Filler slab roofs, lime-pozzolana mix cement, etc can be used for minimizing the embodied energy of buildings. Reddy et al (2001) classified the Embodied energy in three categories -

- Energy consumed in production of basic building materials,
- Energy needed for transportation of building materials, and
- Energy for assembling of various materials to form the buildings

The present study is under third category and deals with the energy analysis of different component of buildings and the overall energy consumption. Bansal *et al* 1999 has elaborated the need to conserve the energy in all sectors of the building Industry. The trends in building industry emphasised by various authors in terms of materials and building components such as walls, roof, windows, and sanitary materials (Bansal *et al* 2001). Particularly energy efficient

materials such steam cured blocks for masonry detailed out by Reddy *et al* 1998 and Walker *et al* 2000. Several energy efficient building and conservation of energy in buildings, particularly the importance of local building materials emphasised by (TERI 2001). The technical know-how and local building materials in housing plays a major role in conserving the energy (DCO 2001).

Especially the terracotta tiles, filler slabs and rat trap bond in masonry advocated by Baker 1992. The use of hollow and in-filled Ferro-cement panels and its cost effectiveness and workability elaborated in tropical climate by Mathews *et al* 1992. The use of concrete and concrete products in building industry particularly in the housing sector (Mohan rai 1992). The embodied energy for various building components with respect to its appropriate technology and its options were argued by Ramesh in 2016. The material specifications and its usage dependent on functional utility and availability so this paper focuses on typical residential building typologies, selection of material and workable appropriate technology to investigate the energy consumption pattern to identify the suitable specifications to conserve energy.

EMBODIED ENERGY IN BUILDING MATERIAL

The energy consumption profiles of newly developed processes and techniques such as semi-mechanized brick making, use of fly-ash in brick making, hollow cement blocks and solid cement blocks etc. and its suitability as well as energy consumption effectiveness are the interest of the present study. The study on different building materials is essential for evolving the energy efficiency in building. Building material production is an important potential area for the use of less energy intensive materials, waste material from agricultural and Industrial process to conserve the energy. (30x110x70mm) has been considered for the comparison and the computations of the energy content of the buildings and masonry.

Quantitative Estimates for Embodied Energy and Cost

In the analysis of quantities, 10m^3 have been considered to produce 10m^3 of wet concrete when deposited in place for different Items of work. In practice for analysis of rates, the reduction in the volume of finished concrete over the sum total volume of ingredient materials is taken as 50% to 55%. For 100m^3 of finished concrete, the sum total volume of dry ingredient material has been taken as 152m^3 as per analysis carriedout by Datta (2001) and observations at the construction site. Similarly for brickwork with cement mortar, considering the wet and dry volumes practically, a conclusion was arrived to increase the dry mortar by 25% and the same is considered for analysis of the quantities. Dry concrete volume can be calculated in the form of –

$$V_{dry\ concrete} = 1.52\ V_{wet\ concrete}$$

Where $V_{wet\ concrete}$ is the actual measurement of slab/ column/ lintel or any other quantity. The widely accepted method in Indian construction Industry for determining the number of materials for 10m^3 of concrete is to divide 15.2 by the sum of the numerals of the proportion of the material, which gives the quantity of material in ‘m^{3}’

A wall of 1.5 times brick thickness has a 30cm nominal thickness. To calculate the quantity of brick and cement mortar the following procedure is followed –

$$V_{wall} = l_{wall}\ b_{wall}\ h_{wall}$$

$$V_{bk+mortar} = l_{bk+mortar}\ bb_{k+mortar}\ h_{bk+mortar}$$

$$V_{brick} = l_{bk}\ b_{bk}\ h_{bk}$$

Total number of standard bricks from *n* number of walls in a building can be expressed as

$$\sum_{j=1}^{n} (V_{wall} / V_{brick+mortar}) W_{breakage}$$

Where, $W_{breakage}$ = 1.05 breakage factor, for $10m^3$ of brickwork quantity 5000 bricks of said size are required. (Standard brick size: 20x10x10cm)

As per construction practice, the mortar joint will be less than 1 cm, the actual thickness of wall has been considered including the mortar joint thickness for quantity estimate.

$$V_{wet\ mortar} = \sum_{j=1}^{n} [(V_{wall} / V_{brick+mortar}) W_{breakage}] [V_{bk+mortar} - V_{bk}] W_{wastage}$$

$$V_{dry\ mortar} = 1.25\ V_{wet\ mortar}$$

The multiplication factor of 1.25 for dry mortar has given by Datta (2001), the actual quantities of materials have arrived with reference to the mixed proportions. The mortar proportion/ mix vary for different items of work; however with reference to the quantities and its proportions of the mix, considering the bulkage and wastage factors the entire quantity estimate has been prepared. Quantity estimates have been prepared for three building cases with three different specification options. The output of estimates is presented in the form of tables which shows the energy content of the materials.

Embodied Energy Estimate of Buildings

Before undertaking the construction of any building it is necessary to know its probable estimated Energy. An estimate is a computation or calculation of quantities required for Embodied Energy consumption likely to be incurred in the construction of a work. The primary object of the estimate is to enable one to know the amount of Embodied Energy spent. The estimate is the theoretical quantity of a work and is determined by mathematics calculation based on the building design and its specifications.

Three buildings cases have been designed to analyze the embodied energy. Detail estimate of building module of a framed structure and load bearing structure has been prepared for all the cases. Brief specifications of Case I, II and III building modules with three different options described in table 1, 2and 3 and the abstract drawings shown in figure 1,2 and 3 respectively below. each case with three options on the basis of the locally available materials and technical know-how been considered and analyzed the energy and cost estimate to appreciate the embodied energy.

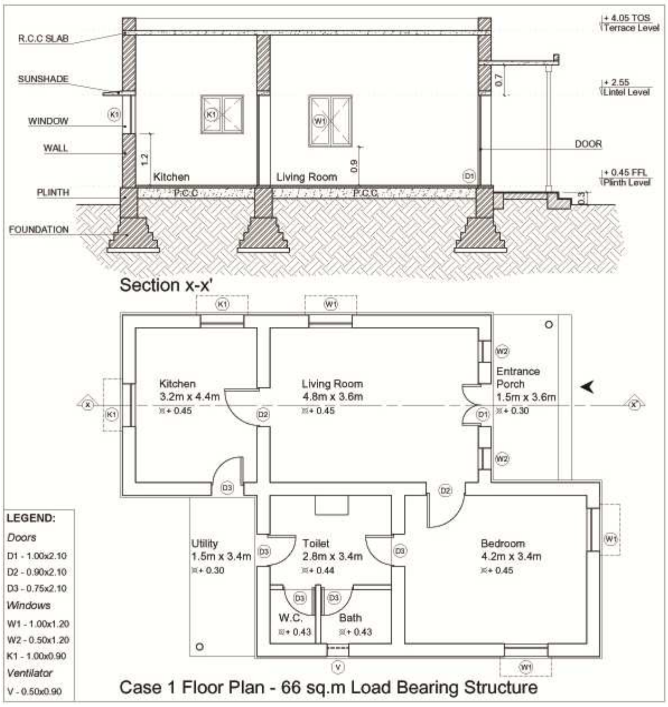

Figure 1: Residential Building Typology 1 – Load Bearing Structure

Table 1: Case-I: One Bedroom unit with Load Bearing Structure having Plinth Area of 66.00m2

Specifications	Option1	Option 2	Option 3
Foundation and Plinth	Class-I brickwork in cement mortar (1:4) over cement concrete	Class-I brickwork in lime concrete	
Superstructure	Brickwork in cement mortar (1:6) over 2.5cm thick DPC (1:2:4) Cement mortar (1:4) for Parapet wall	Fly ash brickwork in cement lime mortar (1:1:6) over DPC	Class-I brickwork in rat-trap bond with cement mortar
Roofing	10cm thick RCC slab using stone aggregate (1:2:4) with 10cm (average) lime terracing	Filler slab with cement concrete (1:2:4) with Mud Puskha terracing	Channel unit roofing with Cavity type mud Puskha terracing
Flooring	Terrazzo flooring in cement concrete using stone aggregate (1:2:4) with neat cement finishing on top	Kota stone flooring	
Finishing	External Walls: 20mm thick cement plaster (1:4) with two coats of colour wash over a coat of whitewash	External Walls: Wall up to plinth including its off-set to have 15mm thick cement lime plaster (1:1:6) with two coats of colour wash over a coat of whitewash	
	Internal Walls: 12mm thick cement plaster (1:6) with three coats of whitewash	Internal Walls: 12mm thick cement lime plaster (1:1:6) with three coats of whitewash	
Doors and Windows	Frames: Sal wood		
	Shutters: Indian teak wood 2.3cm thick. Panelled type design painted with two coats over priming coat. Jambs rear side shall be painted with two coats of coal tar		
	Window grating: 16mm dia MS barrow, MS clamp for frame, 50x6mm flat and 40cm long. Ironwork shall be painted two coats.		

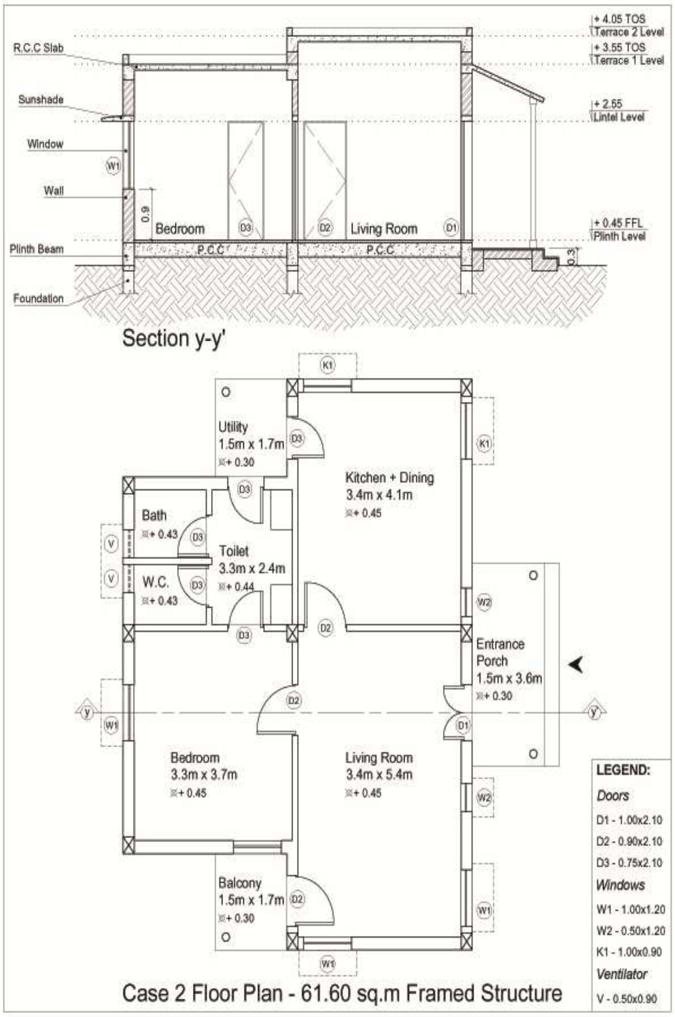

Figure 2: Residential Building Typology 2 – Framed Structure

Table 2: Case-II One Bedroom Unit with Framed Structure having Plinth Area of 61.60m^2

Specifications	Option1	Option 2	Option 3
Structure	Percentage of reinforcement in RCC Floating columns: 0.5% RCC beams: 10% RCC Columns: 1.5% RCC chajjas/ sunshades: 0.5% RCC roof slab: 0.8%	The structure shall have RCC frame with column, lintels. The percentage of steel reinforcement is same as option I for footing, columns, lintels and chajjas	
Superstructure	230mm panel wall: Class-I brickwork in cement sand Mortar (1:6)	230mm panel wall: Class-I brickwork for Rat-trap bond in cement sand mortar (1:6)	Hollow block masonry (400X 200X 200mm)
	115mm walls: Class-I brickwork in cement sand mortar (1:3) with hoop iron 25mm x 1.5mm or equivalent reinforcement at every fourth layer	115mm wall: Class-I brick Work in lime mortar (1:3) with hoop iron at every fourth layer of brickwork	
Reinforced work	RCC works Exposed surfaces: Fair finished with Plastering or floating with cement sand mortar (1:3) of sufficient thickness to give a smooth and even surface.		
Roofing	RCC slab	Filler slab	Pre cast channel unit

Table 2: contd.,			
Terracing	Lime concrete terracing		Mud Puskha over channel unit roofing
Flooring	Kota stone flooring	Terrazzo flooring	Red sand stone in cement lime mortar
Plastering	12mm cement lime plaster (1:1:6)		Cement lime plaster (1:2:9)
	For steps: 20mm cement lime plaster (1:1:6)		
Finishing	External Walls: 12mm thick plaster in cement sand mortar (1:6) finished with two coats colour washing over one coat of white washing		
	Internal Walls: 12mm thick plaster in cement sand mortar (1:6) finished with three coats whitewashing		
	External steps: 20mm cement plaster (1:4)		
Doors and Windows	Class-I teak wood Finished with two coats painting over one priming coat. All chaukhats shall be 12x8cm Door shutters shall be 3cm thick panelled wood		

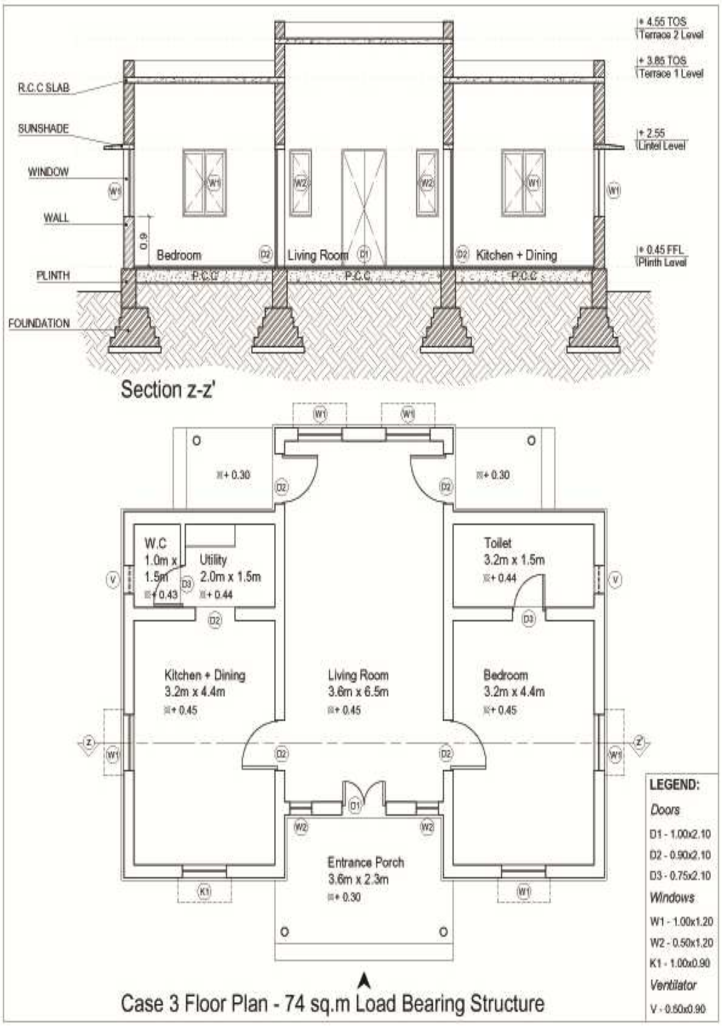

Figure 3: Residential Building Typology 3 – Load Bearing Structure

Table 3: Case-III: One Bedroom unit with Load Bearing Structure having Plinth Area of 74.00m^2

Specifications	Option1	Option 2	Option 3
Structure	Load bearing walls of 230 mm thick		
Foundation and Plinth	Brick in cement mortar (1:4) over cement concrete		Fly-ash Brick in cement lime mortar (1:1:6) over cement concrete
	DPC of 2.5cm thick on cement concrete (1:2:4) with water proofing compound		
Superstructure	Class-I brickwork in cement mortar (1:6)	Class-I brickwork in cement mortar (1:6) for rat-trap bond masonry.	Hollow block masonry
	RCC works using stone aggregates (1:2:4) Reinforcement in RCC work - 1%	RCC works using stone aggregates (1:2:4)	
Roofing	RCC flat roof of 10cm thick	Filler slab roof	Channel unit roofing
Terracing	Lime concrete terracing over 10cm RCC slab (1:2:4)	Lime mud Puskha cavity type terracing over filler slab roofing	Mud Puskha
Flooring	Red sand stone in cement lime mortar		
Finishing	External Walls: Wall up to plinth including off set and steps to have 20mm thick cement plaster (1:4) surface finished with neat cement. Shall be colour washed over two coats of whitewash	External Walls: Wall up to plinth including off set and steps to have 15mm thick cement lime plaster (1:1:6) surface finished with neat cement. Shall be colour washed over two coats of whitewash	External Walls: Wall up to plinth including off set and steps to have 15mm thick cement lime plaster (1:2:9) surface finished with neat cement. Shall be Colour washed over two coats of whitewash
	Internal Walls: 12mm thick cement plaster (1:6) with three coats of whitewash	Internal Walls: 12mm thick cement lime plastered (1:1:6) with three coats whitewash	Internal Walls: 12mm thick cement lime plastered (1:2:9) with three coats whitewash
	Woodwork shall be painted two coats over a coat of priming		
Doors and Windows	Frames: Sal wood provided with necessary iron clamps		
	Shutters: 38mm thick panels of Indian teakwood		Shutters: 30mm thick panels of Indian teakwood

RESULTS AND DISCUSSIONS

Case I: Load Bearing Structure of One Bedroom Unit

Case I is a building having two rooms as shown in Figure 1 placed with a plinth area of 66.00m^2 and the specifications of option I briefed in Table 1

Option I of Case I

Figure 4 shows that the brick in the superstructure, foundation and plinth consumes 49.73% (33.756X10^{6}kcal) **(141.2X10^{3}MJ)** of the energy and is followed by 17.69% (14.14X10^{6}kcal) **(59.1X10^{3}MJ)** of energy consumed by the RCC roof slab. Figure 4 shows the cost estimate of the option I, which gives a similar result that the brickwork costs 40.17% as compared to other items. It is an indicator to give utmost attention towards the material of brick in load-bearing brick structure. It is noted that energy and cost estimate have proportionality to each other. Figure 4 shows the comparison of the percentage of energy and cost that gives certain proportionality between the energy consumption and cost of the building materials. It can be seen from the Figure 4 that total energy consumption of this conventional option I am 67.89X10^{6}kcal **(284 X 10^{3}MJ)** i.e. 1028.62 X 10^{3}kcal **(4306 X 10^{3}MJ)** per m^2. The plinth area cost incurred is at ₹11,638.77 per m^2

Option II of Case I

Figure 5 shows the energy estimate of option II of case I with respect to the specifications given in Table 1. It indicates the total energy consumption and energy consumption per square meter of plinth area in the order of 41.49X10^{6}kcal **(173.7X10^{3}MJ)** and 628.73X10^{3}kcal/m^2 **(2.63X10^{3}MJ/m^2)** respectively. It can be seen from Figure 5 the energy content of fly-ash bricks in foundation and superstructure is in the order of 27.21X10^{6}kcal **(113.9X10^{3}MJ)** i.e. 20% reduction as compared to the option I of the case I. The filler slab of this option consumes 5.51X10^{6}kcal **(23.0X10^{3}MJ)** that reduces the energy content by 61% as compared to RCC slab of option I. The overall cost of construction of option II, Rs.9,194.63 per m^2, is also reduced in the order of 21% as compared to option I.

Option III of Case I

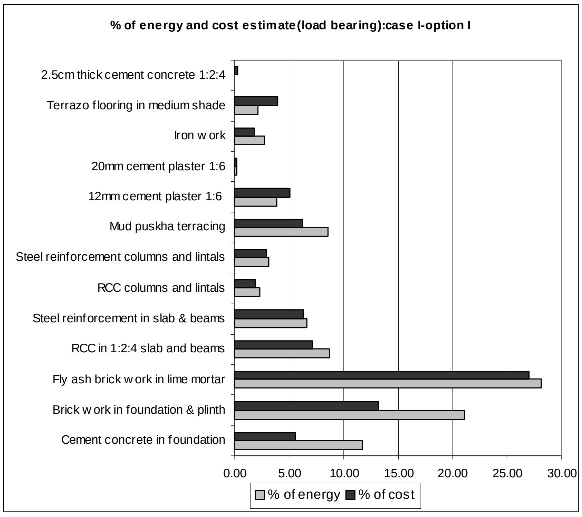

Figure 4: Energy Consumption profile in Case I – an option I

Figure 6 shows the energy estimate and cost estimate of option III with reference to the specifications given in Table-1 respectively. The total energy consumption and energy per square meter of this option are in the order of 45.93X106kcal (192.2X103MJ) and 695.91 X 103kcal (2.913 X 103MJ) respectively. The channel unit roofing shows the 68% and 18.65% reduction in energy content as compared to option I and option II respectively. The overall cost of option III, □9,892.96 per m^2, is also reduced in the order of 15% as compared to the option I the same can be seen in Figure 6. It is seen from this that the energy and cost of Item are in proportion to each other.

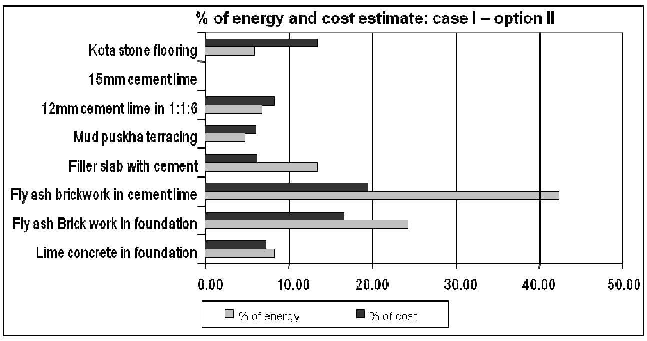

Figure 5: Energy Consumption Profile in Case I – Option II

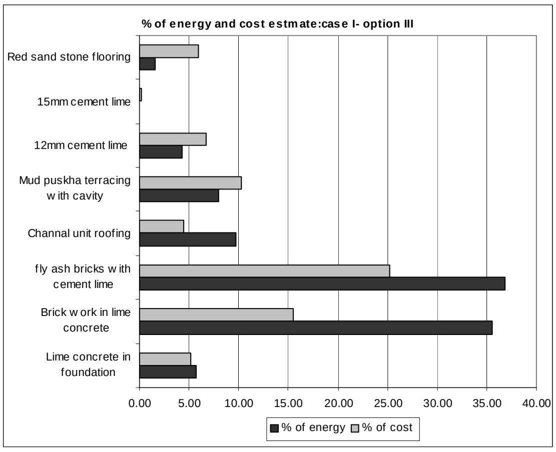

Figure 6: Energy Consumption Profile in Case I – Option III

Case II (Framed Structure of One Bedroom Unit)

Case II is a building of one bedroom unit in framed structure as shown in Figure 2 with the plinth area of 61.60m^2 and its varying specifications are provided in option I, II & III of Table 2

Option I of Case II

Figure 7 shows the energy estimate and cost estimate of option I. The total energy content and energy per square meter is in the order of 57.73X10^{6}kcal **(241.7X10^{3}MJ)** and 937.11X10^{3}kcal **(3.923X10^{3}MJ)** respectively. It is seen from the table that RCC and superstructure consume 42.1% (24.3X10^{6}kcal) **(101.7X10^{3}MJ)** and 31.47% (18.17X10^{6}kcal) **(76.07X10^{3}MJ)** of energy in the building respectively. The energy content in the terracing is in the order of 9.96% (5749.25X10^{3}kcal) **(24.07X10^{3}MJ)**. The Figure 7 shows the plinth area cost to be □12,380 per m^2. It is seen in Figure 7 that the percentage of energy and cost of the different items of construction is in proportion to each other.

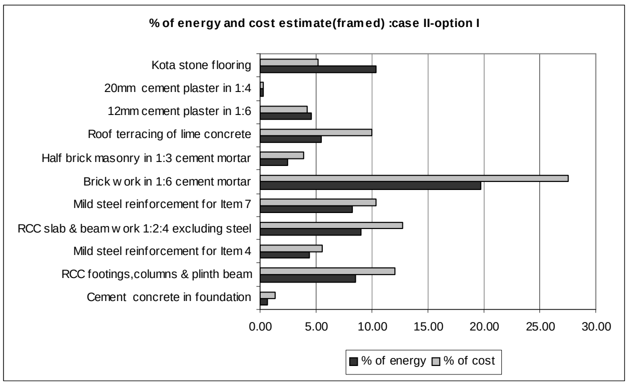

Figure 7: Energy Consumption profile in Case II – Option I

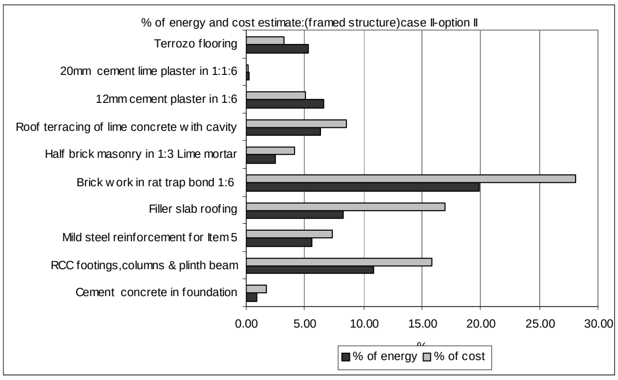

Figure 8: Energy Consumption Profile in Case II – Option II

Option II of Case II

Figure 8 shows the quantitative estimate of option II of energy content 710.49X10^{3}kcal/m^2 **(2.97X10^3 MJ/m^2)** and cost estimate is □9,386.52 per m^2 respectively. It can be seen from the Figure 8 that the cost estimate reduced to 24.18% and energy content reduced to 21.4 % as compared to the option I of case II.

Option III of Case II

The major variation in specifications of Option III are the channel unit slab for roofing, red sandstone flooring, Hollow block superstructure, fly ash curtain walls, mud pushka terracing, and lime cement plastering. Most of these materials are predominantly available for construction. Figure 9 shows the estimate of energy and cost respectively. It is noted that energy content in this option III is 508.63X10^{3}kcal/m^2 **(2.12X10^{3}MJ/m^2)** and the cost estimate is □9,015.12 per m^2. It can be seen from the Figure 9 that the reduction of energy content and of cost estimate are in the order of 46.25% and 27.18% respectively as compared to the option I (Case II). This option shows economical interns of energy as well as for the cost as compared to all the option of case II.

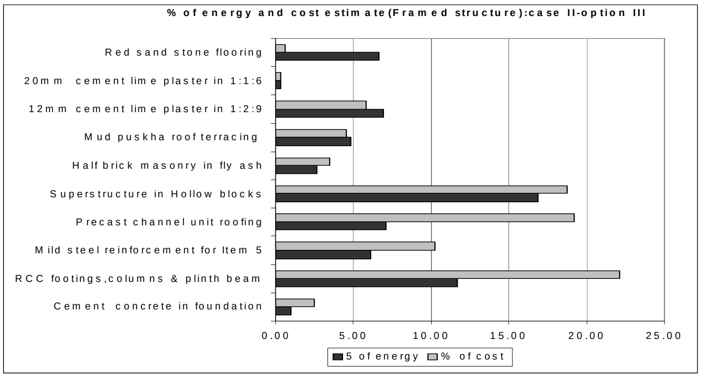

Figure 9: Energy Consumption Profile in Case II – Option III

Case III (Load Bearing Unit of One Bedroom Unit)

Case III is a building of one bedroom unit in framed structure as shown in drawing-3 with the plinth area of 74.00 m^2 and its varying specifications are shown in option I, II & III given in Table III

Option I of Case III

Figure 10 shows the energy estimate and cost estimate of option I. The total energy content and energy per square

meter is in the order of 66.91X10^{6}kcal **(280.1X10^{3}MJ)** and 904.18X10^{3}kcal/m^2 **(3.785X10^{3}MJ/m^2)** respectively. It is seen from the Figure 10 that the cost of plinth area is in the order of Rs.13,960.38 per m^2. It is observed from the figure that superstructure of brick masonry is consuming the maximum energy of 37.29%. The energy consumption for foundation and RCC roof is followed in the order of 20.34% and 18.88% respectively.

Option II of Case III

This option shows the energy content of 703.42X10^{3}kcal **(2.945X10^{3}MJ)** and estimated a cost of Rs.13,960.38 per m^2 as indicated in Figure 11. Figure 11 shows the proportionate relation between cost and energy in terms of percentage consumption. The option II (703.42X10^{3}kcal/m^2) **(2.945X10^{3}MJ/m^2)** indicates the reduction of energy content by 22.2% as compared to the option I of case III (904.18X10^{3}kcal/m^2) **(3.785X10^{3}MJ/m^2)**

Option III of Case III

Figure 12 shows the energy estimate and cost estimate of option III of case III. It indicates that the energy consumption and cost of construction of the building for given specifications is 447.08X10^{3}kcal/m^2 **(1.87X10^{3}MJ/m^2)** and Rs.8,934.65 per m^2 respectively. This option had shown a reduction in the energy content approximately by 50% and 36% in comparison to option I and option II (of case III) respectively.

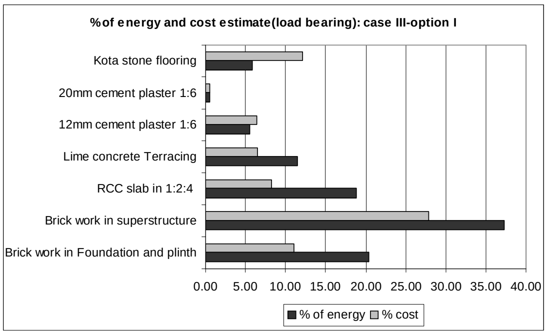

Figure 10: Energy Consumption Profile in Case III – Option I

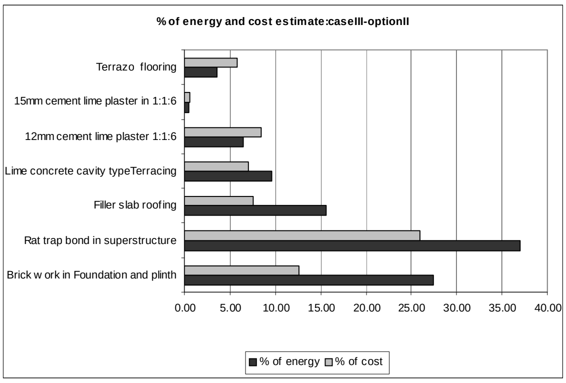

Figure 11: Energy Consumption Profile in Case III – Option II

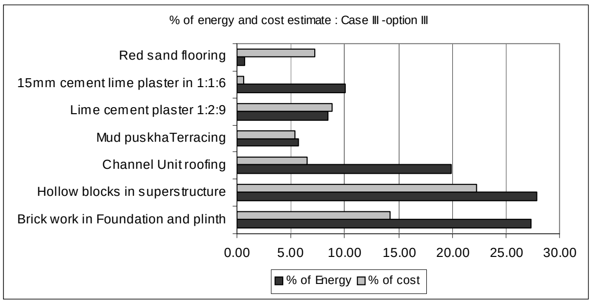

Figure 12: Energy Consumption Profile in Case III – Option III

COMPARATIVE ANALYSIS OF BUILDING CASES

Figure 13 shows the overall comparison of the building cases and its options in relation to energy and cost estimates with reference to the unit area of m^2. The option III of case III shows the maximum reduction of 52.29% in embodied energy as compared to all.

The cost estimate of building materials also shows the reduction in the tune of 27.83% with respect to an option I of Case II. The option II of the case I show the reduction of 32.91% in embodied energy and 25.73% in cost estimate with respect to option I of Case II. The option III of case III indicates that the proper integrated use of alternative and low-cost technologies not only reduces the embodied energy content but also reduces the unit cost of plinth area. The Figure 13 shows that all the options are in proportion to the percentage of energy and cost. The case studies illustrate that the fly-ash bricks, hollow block masonry, channel unit roofing, filler slab roofing, mud pushka terracing, local stone flooring and cement-lime plaster can bring down the embodied energy content to conserve the energy in building Industry.

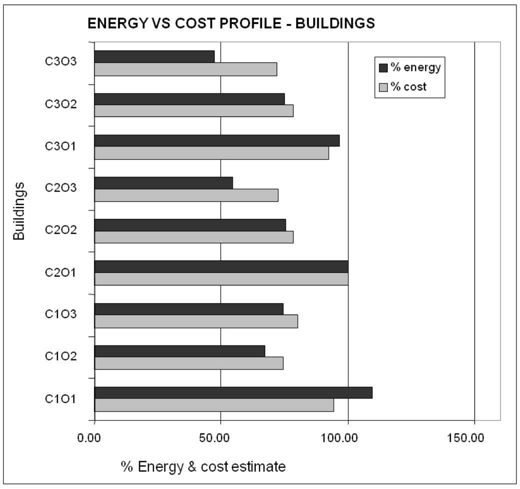

Figure 13

CONCLUSIONS

Embodied energy in basic building materials, different types of masonry materials, mortars, flooring, and roofing system and the cost estimate of buildings have been analyzed with respect to individual components as well as in integrated estimates of buildings. The alternative technologies and less energy intensity materials brought convincing reductions in the energy content of the building materials independently and collectively in the buildings. The case studies and energy analysis mostly indicates that the energy content of the buildings is directly proportional to the cost estimation

of buildings. Lesser embodied energy also contributes to bringing cost-effective buildings. Even though the results are pertaining to Indian conditions, many other developing countries have similar construction practices, where these can be conveniently extrapolated and utilized to conserve the embodied energy.

Significance Statement

This study discovered the potential energy savings in buildings and pave away to provide appropriate less energy intensive specifications with due consideration to Climate change action plans. This study will help to researchers to identify the various components in a building and its related embodied energy and its application to the local context with global objectives. It can be used as a baseline for future investigations of several other building materials and it can be integrated with thermal behavior to work out comprehensive energy savings in building industry.

REFERENCES

1. *Adams, E, Connor, J and Ochsendorf, J. 2006. Embodied energy and operating energy for buildings: cumulative energy over time. Design for sustainability. Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, MA. www.flickr.com*
2. *Bansal, N. K and Cook Jeffrey; "sustainability through Building," Omega Scientific publishers, India.2001.*
3. *Bansal, N. K. "Emerging trends for energy efficiency in Buildings," International Journal of Renewable Energy Engineering, Vol .I, No:3.,Dec'1999.*
4. *(DSR) 'Delhi Schedule of Rates'. 2002, CPWD, Government of India, GOI publications, New Delhi, India. June 2002.*
5. *Dutta, B. N., 'Estimating and costing' 24th revised ed.,Rajkamal Electric press,Delhi.2001.*
6. *Finnveden, G. The Resource Debate Needs to Continue. Int. J. Life Cycle Assess. 2005, 10, 372–372.*
7. *Ramesh, S (2012) 'Appraisal of Vernacular Building Materials and Alternative Technoligies for Roofing and Terracing Options of Embodied Energy in Buildings' Energy Procedia 14 (2012) 1843 – 1848,1876-6102 © 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of the organizing committee of 2nd International Conference on Advances in Energy Engineering (ICAEE) . Doi : 10.1016 / j. egypro. 2011.12.887 ; Available online at www. sciencedirect. com; www. elsevier. Com /locate /procedia ; 2011 2nd International conference on Advances in Energy Engineering (ICAEE 2011) December 27-28, 2011, Bangkok, Thailand.*
8. *Reddy, V. B.V., Jagadish, K. S., 'Embodied Energy of common and alternative Building materials and technologies.' Energy and Buildings 35,129-137.2001.*
9. *Reddy, V. B. V., Lokras. ,S .S., 'Steam cured stabilized soil blocks for masonry construction', Energy and Building 29.,pp29-33.,1998..*
10. *`Hajela, R. B, and Gupta. R. G; "Energy Conservation and Utilisation of inferior fuels in Brick. Production" proceeding on Energy conservation in Buildings, CBRI, Roorkee, India., Nov, 12-14,1992.*
11. *DCO, Build Tech 2001-' Building material and construction Technology to Housing," pp.5-19, 2001*
12. *Kumar V, Jha C N., 'Multifarios applications of fly ash – 'Mission mode approach'.,Fly ash Mission, Proceeding of ' Workshop on utilization of fly ash' at University of Roorkee.,1998.*
13. *Laurie Baker., 'A manual of cost cuts for strong acceptable housing' published by cost ford, centre of science and technology for rural development.,1999.*

14. *Lawson, B. 1996. Building materials, energy and the environment: towards ecologically sustainable development. Royal Australian Institute of Architects, Red Hill, ACT.*
15. *Wani, S. F., Ashish, D. K., Dar, M. A., & Kumar, R. A. V. I. (2015). Study on mix design & hardened properties of self-compacting concrete. Int. J. Civil, Struct. Envir. Infrastruct. Eng. Res. Develop, 5(4), 1-10.*
16. *Lawson, B. 2006. Embodied energy of building materials, Environment design guide, PRO 2. Royal Australian Institute of Architects, Melbourne. www.environmentdesignguide.com.au*
17. *Mathews, M. S., Ramachandriah, A., Sudhakumar, J., Kunhanandan Nambiar, E K., "Thermal performance of Hollow and infilled ferro cement panels in tropical climate," Proceeding on energy conservation in India,Roorkee.,pp:6-9,1992.*
18. *Mathur, S. K., 'Energy efficiency-Lifecycle cost of PVC building materials'., 'Sustainability through building' pp 85-91 .,2001.*
19. *Tomar, A., & Singh, D. Static Analysis, Modal Analysis And Design Modification In Chassis Frame To Optimize Weight By Using Composite Material. International Journal of Mechanical Engineering (IJME), ISSN (P), 2319-2240.*
20. *Mohan Rai. 'Energy conservation in production of building materials' Energy and Habitat., wiley eastern ltd, pp:63-65.,1984*
21. *.Mohan Rai, 'Energy saving in the use of concrete and concrete products in housing' proceedings on energy conservation in buildings (India) Roorkee Nov'1992.*
22. *TERI, Min. of non –conventional Energy Sources 'Energy-efficient buildings in India' TERI and MNEC, 2001.*
23. *Prakesh satya., 'Utilization of agricultural by-products and forest residues in burning of building bricks.' Proceeding on energy conservation in buildings Roorkee., India.,1992.*
24. *Söderholm, P.; Tilton, J.E. Material efficiency: An economic perspective. Resour. Conserv. Recycl. 2012, 61, 75–82.*
25. *ALKAHTANY, L. A. SPACE DESIGN FOR HYPERACTIVITY AND DISTRACTED ATTENTION (METHODOLOGY OF SUSTAINABLE MATERIALS USE).*
26. *Walker, P., Reddy, V B., Masbah, A., Moral, j. C., "The case for Compressed earth blocks construction, in: Proceedings of 6th International seminar on structural Masonry for developing countries. Allied publisher Ltd., Bangalor India, pp: 27-35, October 2000.*
27. *Worth, D., 'Embodied Energy Analysis of Buildings.' Part 1: Determining the energy content of the Building Materials. ESD seminar, Deakin University,Oct 1992.*